REMARKS

Applicants appreciate the thorough examination of the application that is reflected in the Office Action dated May 4, 2007. Applicants add new claims 31-37 which are more consistent in scope with the originally filed claims. Claims 21-37 (17 total claims; 5 independent claims) are pending in the application. Reconsideration of the application is respectfully requested in view of the above amendments and the following remarks.

Art-Based Rejections

Claims 21-30

Claims 21-22 and 26-28 were rejected under 35 U.S.C. 103(a) as being unpatentable over Numata et al. (USPA 2002/0105704) in view of Siegman et al (USPN 6,751,388) and further in view of Aoki et al. (USPN 6,757,499), claims 23 and 29 were rejected under 35 U.S.C. 103(a) as being unpatentable over Numata et al. (USPA 2002/0105704) in view of Siegman et al (USPN 6,751,388) and further in view of Aoki et al. (USPN 6,757,499) and further in view of Edvold et al. (USPN 6,724,956), claims 23 and 29 were rejected under 35 U.S.C. 103(a) as being unpatentable over Numata et al. (USPA 2002/0105704) in view of Siegman et al (USPN 6,751,388) and further in view of Aoki et al. (USPN 6,757,499) and further in view of White et al. (USPN 6, 764,951).

Applicants respectfully traverse these rejections for at least the following reasons.

Prior to describing fundamental distinctions between the cited references and the claimed embodiments, the deficiencies of Numata and Siegman, and incompatibilities of Numata and Siegman, Applicants will briefly summarize features of the embodiments described in Applicant's specification.

Overview

In discussing problems with conventional large core multimode fiber optic cables, the present application discusses that: "Currently, large core multimode fiber optic cables are performance limited in length/data rate product. … In conventional systems, an upper limit for the data transfer rate of a large core multimode fiber optic cable is in the range of 1-10 gigabit per second and it is useful for applications less than 1000 meters in length without repeaters that regenerate the signal." See [0016] of the present application. In addition, the present

application also notes that: "One problem associated with reducing the length/data rate product of large core multimode fiber optic cables is a phenomenon known as pulse spreading, which is equivalent to the waveform degradation described hereinabove.." See [0017] of the present application.

In an embodiment of the high speed optical data transmission system, an input light signal is launched to large core multimode fiber optic cable to excite low order modes. The consequence of launching the power in low order modes for multimode fiber optic cable 200 is that a short pulse will propagate for a long distance with only minimal pulse spreading since the higher order modes are significant contributors to the spreading because of the longer distance they travel. A further benefit in reducing pulse spreading in large core multimode fiber optic cable is achieved by <u>modifying cladding layer to attenuate higher order modes</u>. As described in the present application, for example, with reference to FIGS. 4 and 5, Applicants ran experiments to verify that the length/data rate product of a large core multimode fiber optic cable could be significantly enhanced by launching a light signal to propagate low order modes <u>while attenuating the higher order modes that affect pulse spreading</u>. As discussed in the present application, the test results demonstrate that <u>both initial launching of only lower order mode light and active attenuation of higher order modes contribute to increasing the length/data rate product of a large core multimode fiber optic cable</u>.

Applicants observed that the length/data rate product can be enhanced by <u>selectively attenuating higher order modes without affecting the lower order modes</u>. Large core multimode fiber optic cable 305 is modified to further <u>attenuate the higher order modes</u> thereby increasing the length/data rate product. In an embodiment of system 300, the modal discrimination of large core multimode fiber optic cable 305 is enhanced to damp the higher order modes that contribute to pulse spreading. In general, a length/data rate product of large core multimode fiber optic cable 305 is increased <u>by incorporating absorption loss such that the refractive index of a cladding layer 307 is complex</u>. An example of a methodology to <u>incorporate absorption loss is to dope cladding layer 307 with an absorptive material</u>. <u>Cladding layer 307 is doped to produce a small absorption level that selectively attenuates only higher order modes</u>. To explain further, the lower order modes large core multimode fiber 305 will propagate with very low loss if the index of the core layer n_1 is primarily real (has a very low absorption coefficient). Since very little of the low order modes exist in cladding layer 307, such modes

will only be minimally impacted by the absorptive material. At the same time substantial amounts of high order modes exist in the cladding, and consequently undergo significant attenuations. The absorptive material to dope cladding layer 307 is selected to minimize attenuation of lower order modes while sharply attenuating higher order modes most responsible for pulse spreading effects that limit the length/data rate product of large core multimode fiber optic cable 305.

Thus, when the higher order modes refract to a greater or lesser degree out of the core and propagate partially in the fiber cladding, the higher order modes get filtered out, absorbed and eliminated by the inactive absorbing dopant in the cladding so that higher order modes are not present to cause pulse length dispersion at the output of the fiber and the resultant loss of binary signal being transmitted.

Prior to describing the deficiencies of Numata and Siegman and incompatibilities of those references, Applicants will briefly summarize both of these references and distinctions between those references and embodiments described above.

Numata

Numata employs an optimization approach which requires matching of the lowest order fiber mode(s) diameter to an injected optical signal diameter. More specifically, Numata et al. discloses an optical transmission system S_a in which a lens 112 converges an optical signal OS_{in} outputted from a light emission element 111. The optical signal OS_{in} having passed through the lens 112 enters a multi-mode fiber (MMF) 12. A vertex Z_0 of the lens 112 and an input plane F_{in} of the MMF 12 are at a distance Z_1. The distance Z_1 is set to a value which is not equal to the distance from the vertex Z_0 to the focal point Z_{fp} of the lens 112. As a result, a low-cost optical transmission system can be provided in which the influence of mode dispersion is reduced.

As discussed at paragraph [0060], Numata et al.: "Thus, the present optical transmission system S_a allows the influence of mode dispersion in the MMF 12 to be reduced based on the adjustment of the position Z_1, whereby the transmission bandwidth of the MMF 12 can be broadened. This eliminates the need for a mode separator 84 (see FIG. 13) in the optical transmission system S_a, unlike in the conventional optical transmission system S_{cv}." Numata et

al. attempts to reduce the influence of mode dispersion in the MMF 12 by adjusting the position of Z_1 which in turn reduces the NA_{in}.

In Numata et al., the cladding 122 was composed of a polymer such as methacrylic resin (PMMA). See paragraph [0040] of Numata et al. As noted by the Examiner in the Office Action dated May 4, 2007, "Numata fails to disclose the step of using a step index fiber optic cable having a doped cladding layer for absorptive attenuation of higher order modes."

Seigman

In an attempt to supply this deficiency of Numata, the Examiner cited col. 1, lines 36-47 of Seigman. Applicants note that this passage of Seigman discloses nothing about a "selected doped cladding layer," as recited in claim 21.

Although Seigman and claimed embodiments both relate to optical fibers and the concept of doping part of the optical fiber, Seigman is significantly different from the claimed embodiments and the Numata reference, as will be described below.

Seigman relates to the technical field of **fiber lasers**, whereas the claimed embodiments relate to the field of **communication fibers**. For instance, Siegman's disclosure teaches at col. 4, lines 53-56: "The optical fiber of the invention is preferably used as a fiber laser or as a laser amplifier. When used in these capacities it is convenient to pump the optical fiber through its cladding." These technical fields are significantly different as will be described below.

As discussed in the Abstract of Seigman: "The instant invention concerns optical fibers that have complex-valued V_c -parameters due to gain g established by active dopants that are doped into the fiber core in accordance with a doping profile." (Emphasis added.) Seigman also discusses doping the core of the optical fiber laser, for example, at col. 3, lines 49-52 of Seigman which discusses that: "The optical fiber has a core, a cladding surrounding the core and an active dopant distributed in the optical fiber in accordance with a doping profile. The doping profile establishes a gain g that makes a sufficiently large contribution to an imaginary part of the complex-valued V_c -parameter to define at least one gain-guided mode, e.g., the fundamental mode or several low-order modes of a radiation in the optical fiber." Moreover, as discussed at col. 7, lines 58-61 of Seigman mentions that: "Doping profile 20 is obtained by doping the glass material of core 12 in accordance with any known doping technique." In discussing the cladding layer 14, the Seigman reference which mentions that: "It is noted that

in fiber 10 of FIG. 1 a portion of cladding 14 is also doped. Profile 20 defines a gain g that is highest where the concentration of dopant 18 is highest and drops off with decreasing amount of dopant 18." See col. 7, lines 61-63 of Seigman; emphasis added.

At col. 8, lines 3-10 of Seigman also discusses that: "Cladding 14 is designed to accept and transmit pump radiation 24 at a pump wavelength λ_p for pumping dopant 18 to stimulate emission of radiation 22 at wavelength λ. Pump radiation 24 may be delivered from any suitable pump source, such as a semiconductor diode laser (not shown) and coupled into cladding 14 or directly into core 12." Seigman goes on to discuss that: "When pumped by pump radiation 24, dopant 18 emits radiation 22 that can propagate in any one of a number of modes supported by fiber 10 in accordance with the rules discussed below." See col. 7, lines 61-63 of Seigman; emphasis added.

Claims 21-22 and 26-28

Claim 21 relates to a system for transmitting data at a data rate of at least 10 gigabits per second by preferentially launching input power into a large core multimode fiber optic cable (LCMFOC) to increase a length/data rate product of the LCMFOC. This system comprises:

> a light source for transmitting data from a source as a first light signal, wherein the first light signal comprises a sequence of short light pulses at a data rate of at least 10 gigabytes per second;
>
> a lens having a focal length (f), placed in a path of said first light signal at a distance of approximately said focal length (f) from an end of said LCMFOC, wherein the lens is located to receive said first light signal from said light source and to collimate and focus said short light pulses onto the end of the LCMFOC such that a diameter of focused short light pulses is approximately equal to a core diameter of the LCMFOC to excite low fiber modes and minimize excitation of higher order fiber modes in the LCMFOC,
>
> wherein the LCMFOC is designed to decrease higher order fiber modes which increase pulse spreading that limit the length/data rate product and to thereby increase a transmission distance through the LCMFOC and output second light pulses which include substantially only lower order fiber modes, wherein the LCMFOC comprises:
>
>> an exposed core having the core diameter which receives the focused short light pulses; and
>>
>> a selected doped cladding layer around said exposed core which is selected to excite low order fiber modes of the LCMFOC as said focused

> short light pulses propagate down the LCMFOC <u>and to absorptively attenuate higher order fiber modes</u> generated in said LCMFOC as said focused short light pulses propagate down the LCMFOC, such that: said focused short light pulses propagate through the LCMFOC with reduced short pulse spreading effects that limit a length/data rate product of said LCMFOC. (Emphasis added.)

Claim 26 relates to a method for transmitting data over a large core multimode fiber optic cable (LCMFOC) at a data rate of at least 10 gigabits per second. Claim 26 recites the steps of:

> providing a selected large core multimode fiber optic cable (LCMFOC), wherein the selected LCMFOC comprises: a doped cladding layer around an exposed core having a core diameter, wherein the doped cladding layer is selected to excite low order fiber modes of the selected LCMFOC and <u>to absorptively attenuate higher order fiber modes of the selected LCMFOC which contribute to pulse spreading to increase a transmission distance</u> through the selected LCMFOC; and
>
> providing a source of short light pulses;
>
> providing a lens of a focal length (f);
>
> placing said lens in a path of between the source and the selected LCMFOC at a distance of approximately the focal length (f) from the source; and
>
> transmitting data from said source as a sequence of short light pulses at a data rate of at least 10 gigabytes per second;
>
> focusing the sequence of short light pulses with said lens to collimate and focus said short light pulses onto an end of the exposed core of the selected LCMFOC such that a diameter of focused short light pulses is approximately equal to the core diameter to produce a focused sequence of short light pulses to preferentially launch input power into said selected LCMFOC to excite low fiber modes and minimize excitation of higher order fiber modes in the selected LCMFOC to increase a length/data rate product of said selected LCMFOC,
>
> wherein the <u>doped cladding layer</u>:
>
> excites low order fiber modes as said focused short light pulses propagate down the selected LCMFOC; and
>
> <u>attenuates higher order fiber modes as said focused short light pulses propagate down the selected LCMFOC so that said focused short light pulses</u>

> propagate through the selected LCMFOC with reduced short pulse spreading effects that limit the length/data rate product of said selected LCMFOC, such that second light pulses output by said selected LCMFOC include substantially only lower order modes. (Emphasis added.)

Patentability of Claims 26-30 Over The Cited References

1. Applicants submit that claim 26 is patentable since the cited references fail to teach or suggest every limitation of claim 26.

The Examiner concedes that Numata does not teach or suggest the claimed doped cladding layer. That is, the Numata fails to teach or suggest, for example, a selected LCMFOC which comprises a doped cladding layer that "attenuates higher order fiber modes as said focused short light pulses propagate down the selected LCMFOC so that said focused short light pulses propagate through the selected LCMFOC with reduced short pulse spreading effects that limit the length/data rate product of said selected LCMFOC," as recited in claim 26.

Applicants submit that the other cited references, including Seigman, fail to cure the deficiencies of Numata. Notably, although Seigman hints that a portion of cladding 14 can be doped, the Seigman in no way teaches or suggest that the cladding 14 would "absorptively attenuate," as required by claim 26.

In fact, Seigman teaches the complete **opposite**. As described in detail above, to establish gain in the core of the fiber laser or laser amplifier, Seigman pumps the optical fiber through the cladding so as to stimulate or activate dopant in the core of the fiber. Because the cladding 14 of Seigman is implemented as part of a fiber laser, the dopants in the cladding 14 are "active" since they are optically pumped to emit radiation Thus, the cladding 14 in Seigman acts as a radiator which is intended to produce gain – the exact opposite principle as absorption.

Accordingly, the cladding 14 in Seigman does not attenuate or absorb higher order modes. Therefore, for at least these reasons, the cladding 14 of Seigman is not "selected to … to absorptively attenuate higher order fiber modes generated in said LCMFOC," as required by claim 26. Applicants submit that the other cited references fail to cure this deficiency of Numata and Seigman.

Therefore, Applicants submit that claim 26 is patentable since the cited references fail to teach or suggest at least these recitations of new claim 26. For reasons similar to those discussed above with respect to claim 26, Applicants submit that independent claim 21 is also patentable over the cited references.

2. Applicants submit that claim 26 is patentable since there is no reasonable expectation of success.

Numata relates to an optical transmission system S_a for data transmission which employs optical communication fibers. Seigman relates to the technical field of fiber lasers which operate by pumping light into the cladding so that the light is refracted/injected into the core of the fiber to thereby activate a dopant in the core of the fiber and create a gain.

Applicants submit that one of ordinary skill in the art would not reasonably expect that incorporating a fiber laser as taught by Seigman into the optical transmission system S_a of Numata would work. To the contrary, one skilled in the art would understand that attempting to incorporate a fiber laser into the optical transmission system S_a of Numata would destroy the intended operation of the optical transmission system S_a of Numata.

To explain further, in the fiber laser taught by Seigman, the fiber core must have a dopant that can provide optical gain (not attenuation) at the desired wavelength. In addition, pump light must be injected into the cladding of the fiber so it can be refracted into the core to excite the dopant and generate coherent light in the core. The coherent light generated inside the core is then trapped by the step in the index of refraction between core and cladding, and is guided down the core. Thus, because Seigman relates to a fiber laser, Seigman requires that "pump" light is injected into cladding 14. If the cladding 14 in Seigman's fiber was absorbing (as required by claim 26), pump light would be attenuated, and therefore would not pump the dopant in the core to create the gain, which is a fundamental goal of the fiber laser taught by Seigman. When dopants are not activated by optical pumping, such dopants will not produce a gain, and absorption in the core will prevent ability to propagate the optical signal. As such, the **intended operation of Seigman's fiber laser would be destroyed**.

On the other hand, if one skilled in the art attempted to use the fiber laser of Seigman in conjunction with a high speed optical communications system (such as those taught by Numata), optically pumping the cladding would be counter productive because it would cause

gain rather than absorption in the cladding, thus amplifying rather than attenuating the unwanted higher order modes. The gain media would only be able to react to optical pulses sent down the fiber if those optical pulses were transmitted at a limited bandwidth or rate. That is, active dopant materials (such as those in Seigman) are typically limited to pulse rates in the range of 1-2 gigabits. For at least this reason, significant pulse length dispersion would occur if one attempted to use Seigman's fiber laser in the context of Numata's a high data rate communication system, and therefore the **intended operation of Numata's system would be destroyed**.

Therefore, Applicants submit that claim 26 is patentable since the cited references fail to provide any reasonable expectation of success. For reasons similar to those discussed above with respect to claim 26, Applicants submit that independent claim 21 is also patentable over the cited references.

3. Applicants submit that claim 26 is patentable since the combination of the Numata and Seigman references that is proposed by the Examiner would not work as recited in claim 26.

Applicants submit that the combination of the Numata and Seigman references proposed by the Examiner would not work in the manner that is recited in claim 26.

As noted above, the claimed embodiments relate to the field of communication fibers in which a passive dopant is placed in the cladding to absorb light and thereby attenuate the unwanted higher order modes which are excited in the core of the fiber. This passive dopant is not optically pumped and has no gain.

In stark contrast, Seigman relates to an active fiber laser in which a dopant is placed in the central core of a fiber, and is then optically pumped and excited, which causes the dopant to have optical gain and act as a laser which emits light at wavelengths set by the particular dopant. Nothing about Seigman would suggest the desirability of modifying the system described in the Numata to arrive at the combination of selecting a particular LCMFOC having a doped cladding layer "that is selected to excite low order fiber modes of the selected LCMFOC and to absorptively attenuate higher order fiber modes of the selected LCMFOC which contribute to pulse spreading to increase a transmission distance through the selected LCMFOC," as recited in claim 26. Simply put, a reduction of higher order modes would not

result from the combination of these references so that the signal output from the MMF 12 of Numata et al would include "substantially only lower order modes."

Therefore, Applicants submit that claim 26 is patentable since combining the cited Numata and Seigman in the manner proposed by the Examiner would not work as recited in claim 26.

Claims 21-25

For reasons similar to those discussed above with respect to claim 26, Applicants submit that independent claim 21 and its dependent claims 22-25 are also patentable over the cited references.

New Claims 31 and 32

Applicants submit that new independent claim 31 and its dependent claim 32 are also patentable over the cited references for reasons similar to those discussed above with respect to claim 26. For example, Applicants submit that the cited references fail to teach or suggest, for example, "a doped cladding layer around said exposed core of said large core multimode fiber optic cable that attenuates higher order modes generated in said large core multimode fiber optic cable to reduce pulse spreading effects that limit a length/data rate product, and wherein said refractive index of said doped cladding layer includes a complex component that attenuates higher order modes such that a third light signal output by said large core multimode fiber optic cable includes substantially only lower order modes," as recited in claim 31. Moreover, there is no reasonable expectation of success and the proposed combination of Numata and Seigman would not work for at least the reasons discussed above with respect to claim 26.

New Claim 33

Applicants submit that new independent claim 33 is also patentable over the cited references for reasons similar to those discussed above with respect to claim 26. For example, Applicants submit that the cited references fail to teach or suggest, for example, "using the doped cladding layer to attenuate higher order modes of said light pulses as said data transmission propagates down the large core multimode step index fiber optic cable to reduce pulse spreading effects that limit a length/data rate product such that second light pulses output

by said large core multimode step index fiber optic cable includes substantially only lower order modes," as recited in claim 33. Moreover, there is no reasonable expectation of success and the proposed combination of Numata and Seigman would not work for at least the reasons discussed above with respect to claim 26.

New Claims 34 and 35-37

Applicants submit that new independent claim 34 and its dependent claims 35-37 are also patentable over the cited references for reasons similar to those discussed above with respect to claim 26. For example, Applicants submit that the cited references fail to teach or suggest, for example, a "doped cladding layer is designed to absorb higher order modes to reduce pulse spreading effects that limit said length/data rate product," as recited in claim 34. Moreover, there is no reasonable expectation of success and the proposed combination of Numata and Seigman would not work for at least the reasons discussed above with respect to claim 26.

In conclusion, for the reasons given above, all claims now presently in the application are believed allowable and such allowance is respectfully requested. Should the Examiner have any questions or wish to further discuss this application, Applicants request that the Examiner contact the undersigned attorney at (480) 385-5060.

If for some reason Applicants have not requested a sufficient extension and/or have not paid a sufficient fee for this response and/or for the extension necessary to prevent abandonment on this application, please consider this as a request for an extension for the required time period and/or authorization to charge Deposit Account No. 50-2091 for any fee which may be due.

Respectfully submitted,

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